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UTILISATION OF GEOTHERMAL WATER IN THE RIGA/JURMALA REGION OF LATVIA FOR RECREATION AND HEALTH. PRE-FEASIBILITY STUDY FOR AN OUTDOOR THERMAL SWIMMING POOL

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ABSTRACT

The main objective of this study was to investigate whether the relevant site specifics, the surrounding tourist attractions and general conditions of the geothermal resources in the Riga/Jurmala region would justify the investment required to refurbish and operate a modern international health spa with related tourist facilities. The study shows incontestably that the use of the very old sedimentary water of the Riga/Jurmala region of Latvia, which has excellent balneological properties, is both technically and economically feasible.

The study describes in detail a proposed outdoor swimming pool health spa based upon the use of geothermal water for therapeutic and health cures. The cost estimate for the facility, which can accommodate some 500 visitors per day, comes to about 4,200,080 USD. The total capital investment will assumedly be provided 60% by borrowed money and 40% from equities. The loan period is assumed to be 7 years at 8% interest, with a grace period of 2 years. An economic viability assessment for the facility yields an internal rate of return of some 20% and a discounted payback of some 5 years based upon the above loan terms, a discount rate of 12% and a 25 year economic life span. The assessed economic viability may be deemed quite acceptable for this type of project.

1. INTRODUCTION

This report addresses, in outline, the potential for commercial utilisation of geothermal energy in the Riga/Jurmala region of Latvia in the recreation and health industry. It moreover specifies an outdoor swimming pool project, and a pre-feasibility study to assess its potential economic and technical feasibility.

Latvia is situated in Northeast Europe on the east coast of the Baltic Sea (Figure 1). Some 500 km of the

FIGURE 1: The Latvian Republic and location of the study area

Latvian 1800 km long border is coastline. The long sandy coastline makes Latvia especially attractive to tourists. Groundwater, particularly mineral water, is developed almost everywhere in Latvia.

Recent changes in the Latvian social and public health policy promote the use of geothermal hot water in balneological applications. Any study into the use of geothermal water for an outdoor swimming pool or health spa development in Latvia, entails not only investigating the use of the earth's heat in the form of thermal water with temperatures of 25-50°C, but also the use of its balneological and therapeutic properties for health spas and recreational activities for foreign and local tourists. Multifarious integrated use of the geothermal resource is generally more cost-effective and profitable, than singular direct use, for example in heating, etc. Windmills in the Baltic coastal region of Latvia provide the alternative energy share in the total Latvian energy supply, which at the moment comprises less than 0.1%. Geothermal energy is recognised worldwide as an environmentally benign alternative energy resource, particularly low-temperature geothermal energy. It has been estimated that using the geothermal energy indicated by Latvian thermal anomalies might satisfy as much as 18-20% of the country's forecasted future heat demands (Eihmanis, 2000). This would be a significant contribution towards Latvia achieving the environmental contamination abatement goals demanded in the EU directives, and the undertaking in the Kyoto Protocol. For a more profitable utilization, however, the balneological properties of the Latvian thermal water should also be made use of.

The importance of health resorts and spas in the public health sector is basically as follows:

- Classical therapeutic use of geothermal water is beneficial in prevention and rehabilitation;
- The geothermal water provides economic alternatives for the regional health care industries and health tourism markets;
- They promote better health and healthy recreation habits.

1.1 Principal objectives

Low-temperature geothermal energy has been used cost-effectively in a number of countries where appropriate geological, hydrological and geophysical conditions are present such as in sedimentary strata. Examples of this are found in European countries like Romania, Slovakia, Serbia, France, Poland and Hungary. In these countries geothermal water is successfully used for fish farming, in heat pump applications, horticulture for greenhouse heating, for space heating, for animal husbandry, in industry for drying products, in balneological and recreational applications such as swimming pools, health spas etc. In Latvia, there are many possibilities for direct use of geothermal energy, particularly for health spas.

The geothermal waters of Latvia have typically much higher concentrations of dissolved solids (TDS) compared to those of other countries. This high TDS and the associated balneological and therapeutic properties of geothermal water is something that can be advantageously used in the domestic health industry to help increase profit and marketability.

The project, which is the subject of this study, has the following four principal objectives:

- Use of geothermal energy as an additional energy source, independent of imported energy sources;
- Utilise the balneological and therapeutic properties of the local geothermal water in combined

bathing and health spa applications for curing, and treatment for prevention and rehabilitation;
- Expanding existing resort facilities for national and foreign tourism;
- Reduction of environmental pollution.

The development of a health spa close to the two cities most popular with foreign tourists (Riga and Jurmala) has great potential for expanding and improving the economy of tourism in Latvia.

The aim of the study is to identify and appraise the most suitable location for such a health spa, considering the suitability of existing physical facilities, and to describe and evaluate the general conditions and facilities available locally. The study is also to establish, through relevant chemical and other special analyses, the balneological characteristics of the available geothermal and mineral waters.

1.2 Short description of the present situation and envisaged future situation

Far-reaching changes have taken place in the economic situation within Latvia since the country gained its independence from the Soviet Union on the 6th of September 1991. Energy prices have increased and a number of old factories have been closed, and development of geothermal utilisation has ceased. The energy crisis that has hit all post-soviet countries has brought about increases in energy prices (oil, coal, gas) which are still ongoing.

Nowadays in Latvia, as elsewhere in the world, people look towards the harnessing of renewable alternative energy sources as a potential measure of abatement to the ever increasing greenhouse effects. Of these, geothermal energy has probably the greatest potential (Table 1).

In the period 1990-2050, the primary energy consumption in the world is expected to increase by 50% according to the most environmentally conscious scenario, and by 275% according to the highest growth rate scenario.

TABLE 1: Direct heat production in the world from renewable energy (Fridleifsson, 2001)

Renewable energy type	Capacity factor (%)	Turnkey investment cost (USD/kWh)	Current energy cost US¢/kWh	Potential future energy cost USD/kWh
Biomass	25-80	250-750	1-5	1-5
Geothermal	20-70	200-2000	0.5-5	0.5-5
Solar heat	8-20	500-1700	3-20	2-10

In Latvia there are only a few places where geothermal energy is still in use, such as a small swimming pool in the hotel "Baltija" and a fish farm near Dobele. Both of them are, however, in the old soviet style and not energy efficient. There are no outdoor swimming pools in Latvia. The existing indoor swimming pools are mostly intended for sport purposes rather than for tourist recreation and health. In the study area the surroundings are beautiful and much sought after by tourists, borne out by the fact that last year about 1,4 million tourists visited Latvia. This number is expected to increase in the next years, especially if more tourist facilities are developed.

1.3 Geothermal prophylactics and therapy

The use of geothermal water for bathing, therapeutic purposes and recreation represents man's oldest known use of geothermal resources. The culture of balneology goes back to ancient times. This culture has been particularly prestigious in Central-Europe and Japan. In Europe there are currently in operation several hundred spas, which are visited by tens of millions of guests every year (Ohtsuka and Agishi, 1996).

At present there does not exist an internationally accepted definition of mineral water, which will hold in law. Certain common points are, however, found in all commonly used definitions. The main principle is that mineral water is always considered as being "natural water obtained from natural springs or artificially opened wells". For water to be classified mineral water, it must contain a minimums of 1,000 mg/kg total dissolved solids (TDS) or more than 250 mg/kg of carbon dioxide. This value has been specified for medical re-convalescence, and health spring water centres by "Deutchen Baaderverband",Germany (Fresnius et al., 1995). Other countries in Europe accept this value. Under this specification, geothermal water in the wells in Riga/Jurmala region qualifies as mineral water, the values for their water being more then 100 times more than required. TDS content in this water is more than 3 times higher than that in the famous "Blue Lagoon" in Iceland (Appendix, Table 1) and the chemical composition indicates that this water could have very favourable impact on the skin.

The temperature of the spring water does not constitute a basic criteria for the definition of mineral water. In the thermal resort "Montecatini" (Italy), the source Tettuccio temperature is just 24.6°C, and in "Vittel" Grande Source (France), the temperature is 11°C. The thermal effect of medical water, as far as the effects of therapy are concerned, may be summarised as follows (GTC and VO, 1988). Vasodilatation increases in the veins of the skin, thereby accelerating the metabolic processes in the cells of the skin. In addition to the physical activity, the mechanical force caused by the motion of water molecules provides a micro-massage. In this way capillary dilatation and blood circulation improve, oxygen supply is increased and the metabolic processes are intensified in the skin and subcutaneous cells.

In addition to geothermal effects, it has been discovered that waters high in mineral salt content have diverse beneficial chemical effects on diseases through the absorption of a certain quantity of the dissolved mineral materials via the skin. A good example of this is the utilisation of sulphurous water (Harkany in Hungary) where, according to isotope tests, the sulphide water penetrates the skin 8-10 times faster then sulphate. As a result, the skin veins first contract and then dilate. An additional benefit is a non-toxic inflammation reduction, desensitising and parasite killing effect. A significant part of the absorbed sulphur is stored in the skin and can be detected in the skin and in hair for weeks after bathing. A similarly outstanding medical significance is attached to the free carbonic acid coming from the ground with the geothermal water which, during a carbonic acid bath treatment, intensively improves blood circulation and is therefore of significant medical importance for circulatory and heart disorders. This method is for example used in the well-known Heart Clinic of Balatonfüred (Hungary).

Health benefits due to the thermal effects of balneological water can also be quite significant. The pulse rate and cardiac output begin to increase once the water temperature reaches 38°C or higher. Capillary vessels, arterioles and venues begin to dilate in the peripheral circulatory system, and an increase in volume and the rate of blood flow and a decrease in systemic vascular resistance are noted. This reduces loads on the heart since dilation of the venous system reduces the cardiac pre-load as a result of an increase in the venous blood pool and a decrease in the venous return. The use of thermal waters in hot pots is, thus, useful, for relaxation and the treatment of some nervous disorders.

Treatment with geothermal water also proves beneficial against disorders of the digestive tract. The geothermal water contains various mineral salts (the most important of these being bicarbonates), which find excellent application as drinking cures. Sodium chloride water may be used for female disorders, with very favourable medical results. Iodine can be absorbed by the sebaceous gland. Carbon dioxide and hydrogen sulphite affect the microcirculation in the body, markedly dilating peripheral vessels and enhancing vascular motion.

The therapeutic importance of the mineral solutes and gases carried in natural water from springs and boreholes have been mentioned by many (see e.g. Björnsson, 2000). Calcium, magnesium, sodium, chlorides, and sulphates are most common to water considered to have therapeutic properties. Carbonated water is used primarily to treat cardiovascular disorders; alkaline water is recommended for some gastrointestinal and urological disorders.

1.4 Balneological classification of mineral water

In the context of this report, mineral rich water is defined as water having beneficial effects on health. Making use of these minerals will, therefore, be important to the curative effect and its classification will only be of interest in as much as it will group together mineral water having similar therapeutic uses. It would, therefore, seem logical to classify according to therapeutic uses, such as water active on the digestive system, water active on the cardio-vascular system, etc. Most often experiments have shown the mineral water acts on the major physiological regulatory functions of the organism such as affecting the neiro-vegetative equilibrium, the calcium metabolism, etc. It is fitting to say that the associate materials of mineral water (mud and gas) can also have significant medical use and that knowledge of them is, therefore, important. Table 2 (MWLTRK, 1990) features the principal physiological properties and principal medical uses of different kinds of mineral water.

TABLE 2: Balneological effect according to chemical classification of geothermal mineral waters

Chemical type of mineral water	Principal physiological properties	Principal medical use
Bi-carbonated water	Stimulating action on the hepatic and intestinal function, on certain general metabolism (excretion of uric acid, hypo-glycemiating effect)	Gastro-intestinal illness; hepatic insufficiency; gout
Sulphated water	Stimulating action on the billary and intestinal function; diuretic action gastro-intestinal illness	Hepatic insufficiency; problems with accumulation of organic waste
Sodium chlorinated water	Stimulating action on growth and cicatrisation (osseous tissue in particular)	Podiatry; after effects of osteo-articular traumatisms; chronic infection of the mucous membranes
Sulphurated water	Trophic effect on the skin and mucous membranes; antalgic, antispasmodic action	Chronic infections of the mucous membranes; rheumatology; spasms (digestive in particular); metabolic illness

2. BACKGROUND INFORMATION

2.1 Geographical setting

Latvia is situated on the Baltic coast and borders Estonia in the north, Lithuania in the south, the Russian Republic in the east and Belorussia in the southeast (Figure1). Geographic coordinates are 57 00 N and 25 00 E. The coastal plain is mostly flat, but inland to the east the land is hilly with forests and lakes. About 43% of the country is covered with forests, 10% consist of peat bogs, 2-3% of freshwater reservoirs, 40% is agricultural land and 4% is taken up by towns, villages and roads. Latvia has an area of 64,589 km^2 and its population is some 2,600,000. Riga (population 900,000) and Jurmala (population 60,000) are situated on the southern shore of the Bay of Riga (Figure 2).

FIGURE 2: Map of the Riga / Jurmala region (study area)

Riga is the capital city of Latvia. It is situated on both sides of the biggest river in Latvia – Daugava, near the coastline. In the eastern part of the city a beautiful lake is found called Baltezers. The landscape is smooth-faced, with no mountains and very few hills.

The territory of *Jurmala* occupies a narrow strip of land some 30 km in length, of which 25 km are on a peninsula between the sea and the river Lielupe flowing parallel to it. In the territory of Jurmala the sandy beach enters the sea at a very shallow angle and the depth of the water increases very slowly. The width of the beach is 150-200 metres and it is edged by a strip of dunes and forest. The beach area is about 90 km^2 and the Jurmala City centre is some 22 km from Riga (Figure 1). Forests and parks occupy about 3000 ha of land. They mainly consist of conifers, mostly pine trees, the tallest of which reach up to 40 m in height. Leaf-bearing trees - oaks, lime, maple, beech, elm and alder may be seen only in special areas. Some trees can attain a gigantic size; the most beautiful of them is a giant oak in Kauguri, at the corner of the Kaugurtsiems and Captain Zolts streets.

The *Kemeri National Park* (KNP) was founded in 1997. It is the second national park in Latvia after the Gauja National Park. Its aim is to foster nature by conducting a non-destructive manner of management and to secure the conservation of the natural environment within the precincts of the Reservation in order to preserve its unique natural resources. The territory of the KNP covers 43 ha. It includes part of the township of Jurmala west of Kauguri and Sloka, including the Great Kemeri Swamp, as well as the village of Kemeri and its health resort.

2.2 Climatic conditions

Climatic conditions in Jurmala can be characterised as maritime, namely wet and having moderate winter temperatures (Table 3). The low-lying sandy district displays prolonged winter periods without frost, as a rule. In Riga/Jurmala frost sets in about November 25th. The period free of frost lasts for about six months at the seaside.

TABLE 3: Average monthly temperatures and precipitation in Jurmala

		Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Highest temp.	°C	-3/-1	-3/-1	2/4	9/11	15/17	19/21	21/23	20/22	15/17	10/12	3/5	-1/1
Lowest temp.	°C	-9/-7	-9/-7	-6/-4	-0/2	5/7	9/11	11/13	11/13	7/9	3/5	-1/1	-6/-4
Precipitation	mm	35/40	25/30	30/35	40/45	45/50	60/65	75/80	75/80	75/80	60/65	60/65	45/50

2.3 Existing tourist attractions

Following Latvia's political and economical independence in August 1991, tourism has flourished more and more. Many thousands of tourists from the whole world come to Eastern Europe and also to Latvia every year to experience the Baltic culture and visit some of the country's tourist attractions. The levels of tourist facilities have vastly improved in phase with the fast progress in the Latvian economy. The biggest attractions to international tourism are provided by Latvia's capital Riga, and Jurmala, the largest resort town in the country.

The main attractions of Riga to Europeans are the Jugendstyle buildings in the old town, parks, service and shopping. An acceptable number of evening and night entertainment choices are also available in the city. The most popular for foreign visitors to the area are the National Opera, the restaurant "Lido" near the biggest Latvian river called Daugava, the coast, nightlife in the Old Town of Riga, Central Market, and Sigulda (a historical place near Riga). In the summer of 2000 the total number of tourists in Latvia was about 1.9 million. These numbers could be increased by creating more facilities for foreign tourists and by advertising possibilities for tourism in Latvia in western countries.

There are many enticing sights that are worth seeing. Riga is very diverse in character. For example, the Old Town - the most ancient part of the city that has been preserved from the 13th century. Others might be interested in the Jugendstyle architecture and the boulevard ensembles that were formed at the end of the last century and have been nominated to the list of the world's architectural monuments by UNESCO experts. Riga is also called the city of parks and gardens. The hectic present day life and modern tendencies towards rapid development are reflected in the commercial offices, banks, and other business buildings being built mostly in the central part of the city. It is worth visiting churches, castles, cinemas, museums, art galleries, theatres, exhibition halls, cultural centres, the zoo, and the botanical garden. Tourism services (they are comparatively cheap in Riga) - hotels, restaurants, cafes, and shops - are located in the city centre.

Jurmala, a resort town possessing 15years of resort traditions, is even more attractive in the summer time. It offers 30 km of the finest sandy beaches with elegant residences among the pinewoods, making it the Riviera of the Baltic. There are many hotels, sanatoriums and entertainment facilities. Jurmala is also only 14-60 km from Riga and boasts good road and rail communication facilities. Kemeri, a small town close to the National park, also features an exceptionally elegant sanatorium.

The Great Kemeri Swamp is a rather unique phenomenon owing to the interaction that takes place between the basic bedrock and the swamp in the whole of Kemeri territory. The interaction yields sulphuric water, the most valuable medicinal produce of Kemeri, and has been known to the local inhabitants for many years as the Holy Spring of Kemeri. On the whole, the KNP reveals a very rich biological variety; forest covers 51%, swamps 24% and water 10% of the park area. The forestland is inhabited by numerous species of animals, such as stags, wild boars, fallow deer, and wolves. The expanses of swamps serve as grazing areas for elks; the water serves as domicile for beavers, etc.

A quarter of all the plants listed in the Red Book of Latvia (Latvian Book of Preserved Species) grows in the Park. Many species of birds (73% of all the species of birds inhabiting Latvia) may be seen there, among them are many that nest only in the Kemeri swamps and cannot be seen anywhere else in Latvia and are also protected by the Red Book. The National Park also boasts considerable international ornithological significance. It is intended to serve as an undisturbed resting-place for migrating birds. A considerable number of objects in the KNP are included in the database of the Coordination Program of Environment Information (CORINE).

The most urgent need is to further develop public swimming pools and health spas in order that they reach the level of other existing health facilities. In Riga and in Jurmala there are some indoor swimming pools and in Jurmala a few spa-hotels. But one of the main problems with existing tourist facilities is, however, that nearly all of them are since Soviet times and in bad condition.

2.4 Energy and balneological resources

2.4.1 Geological settings

Latvia is located in the western part of the East European Platform and is, thus, characterised by the occurrence of almost horizontal sediment layers. These geological features result from the non-uniform character of the directions and amplitudes of the crustal tectonic movements. The pre-Baikalian tectonic cycles have influenced the structure of the crystalline basement only, while the sedimentary cover with various structural stages was formed during the following cycles. Siltstones grow in abundance to the north and east, whereas clay content is maximal in central and southeast Latvia. The well sorted fine- and medium-fine-grained sandstones are the most common lithologies of the main part of the Cambrian of western Latvia, but they also dominate the upper part of the Cambrian section in central Latvia and the northern part of eastern Latvia.

Porosity and permeability of the sandstones across the study area vary from 25 to 32% and 500-1100 mD in shallow setting to 0.7-5% and 0.0001 mD in the deep part of the basin, though considerable deviations from this general trend have been documented (Huenges et al., 2000). Some properties of the rock are listed in Table 4. The most considerable scatter of porosity values were stated for shallow reservoirs. At depths of 1-1.8 km, porosity of sandstones and siltstones systematically decreases to 10-20%, though locally reaching 25-30%. Magnetic susceptibility in the central part of the basin measures 5.9×10^{-5}.

TABLE 4: Properties and composition of siliciclastic rocks in the Baltic Cambrian basin at the depth 1-1.8 km (mean value)

Rock type	Sandstones	Siltstones
Porosity (%)	14.4	13.8
Wet density (s) (g/cm^3)	2.3	2.4
Dry density (g/cm^3)	2.15	2.24
Grain density (g/cm^3)	2.51	2.6
Magnetic susceptibility, k	1.8×10^{-5}	13.9×10^{-5}
NRM (A/m)	2.6×10^{-3}	0.88×10^{-3}
SIRM (A/m)	168.8×10^{-3}	481×10^{-3}
Tc (W/mk)	3.96	3.57
SiO_2 (%)	96.4	79
Al_2O_3 (%) (as indicative of clay content)	1.23	8.24
CaO (%) (as indicative of carbon. cement)	0.34	1.16

2.4.2 Specifics of the geothermal reservoir

In the southwest part of Latvia there is situated a geothermal anomaly, which covers about a quarter of the country (Figure 3). These Latvian geothermal resources are concentrated in the Lower Devonian (D1km) and Cambrian (Cm2dm) aquifers in the form of low- enthalpy water (Figure 4). Geothermal water having noteworthy thermal power and balneological properties may be obtained from Cambrian aquifers, which are located in an area of 12,000 km^2 in the central part of Latvia at depth of 850-1,730 m.

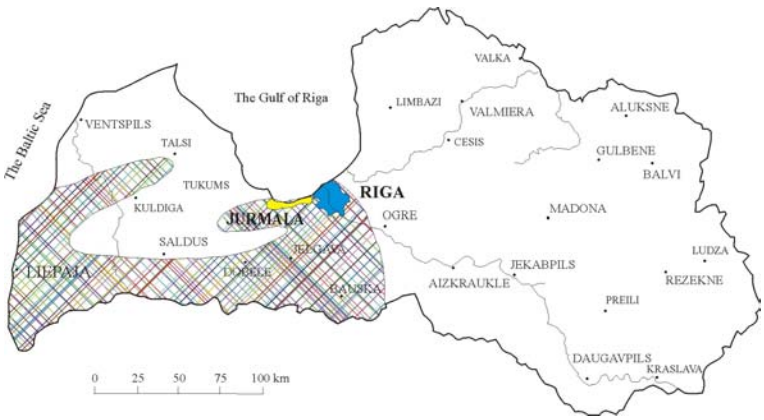

FIGURE 3: The geothermal anomaly of Latvia

In the Jurmala region there is an aquiclude located at a depth greater than 300m, which effectively insulates the Cambrian aquifer from other water-bearing layers. Some general characteristics and heat potential of the aquifers are shown in Table 5 (Huenges, 2000).

TABLE 5: General characteristics and heat potential of the aquifers

Aquifer	Geothermal area, 25°C (km$^{2)}$	Gross aquifer rock volume (10^9 m^3)	Net aquifer rock volume (10^9 m^3)	Water volume (10^9 m^3)	Av. aquifer temperature (°C)	Techn. heat resource (10^{18} J)	Econ.heat resource (10^{18} J)
D1km	1,000	150	99	23	29	5.4	3.4
Cm2dm	12,000	1,260	604	85	44	46.4	35.4

The distribution of temperatures in the Cambrian formations approximately follows the depth configuration (Figure 5). The basin flanks are affected by cooling from meteoric water. The geothermal gradient also reflects variations in heat conductivity of the formation rocks. Aquifers have lower values of geothermal gradient (15-30°C/km). Moreover, geothermal gradient values vary laterally from 10 to 50°C/km, mainly due to differences in heat flow density.

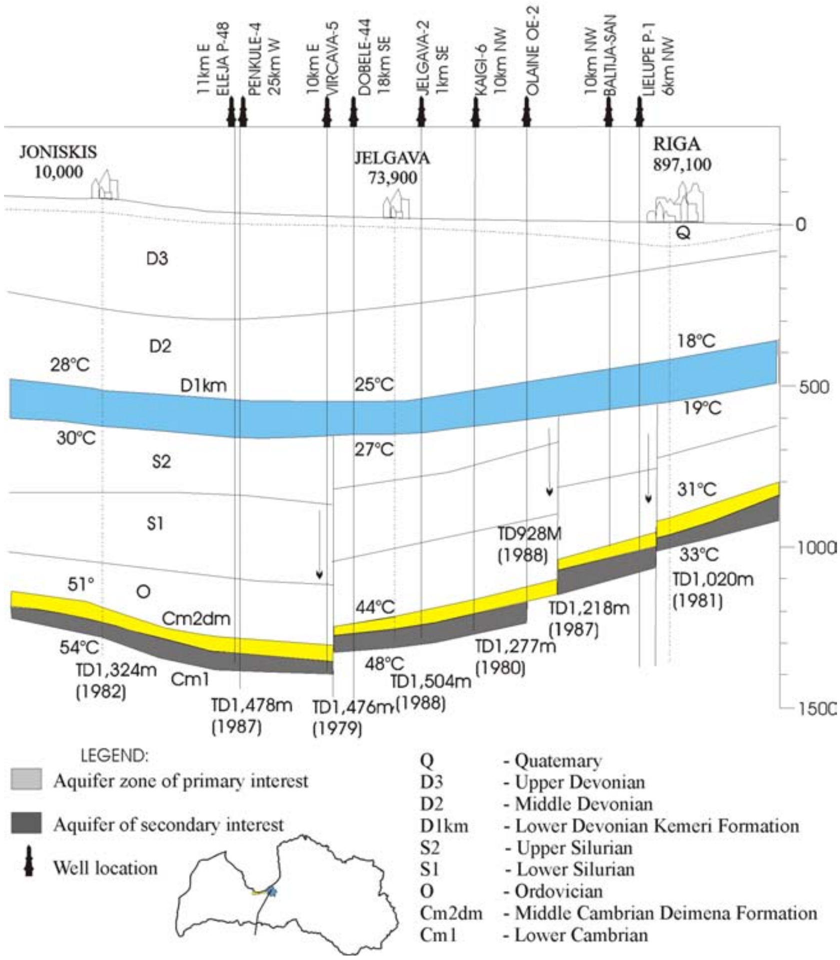

FIGURE 4: Geologic cross-section through the geothermal anomaly

The Masury-Belarus high in the south and the southern flank of the Fennoscandian Shield in the north, represent the recharge areas of the aquifer. In the east and north the basalt portion of the Pretrilobitic Cambrian represents a common aquifer with the Vendian one and is separated by the thick Cambrian clay package from the Trilobitic Cambrian aquifer, which is a part of the common hydrogeological system with Ordovician, and Silurian carbonates. The Cambrian-Vendian aquifer is constrained in the east and north and is composed of the Rovno-Vendian sandy deposits overlain by impermeable Lontova–Lükati clays, which still give way to sandy lithofacies westward proximal to the palaeoshore of the basin. The transmissivity in the relatively coarse-grained Voosi sandstones is about 100 m^2/d. The zones of the Baltic basin where the temperature exceeds 30°C store $0.6x10^{12}$ m^3 of geothermal water, from which as much as 100,000 PJ of heat energy can be obtained. The German company "Geothermie Neubrandenburg" in cooperation with local entities carried out studies

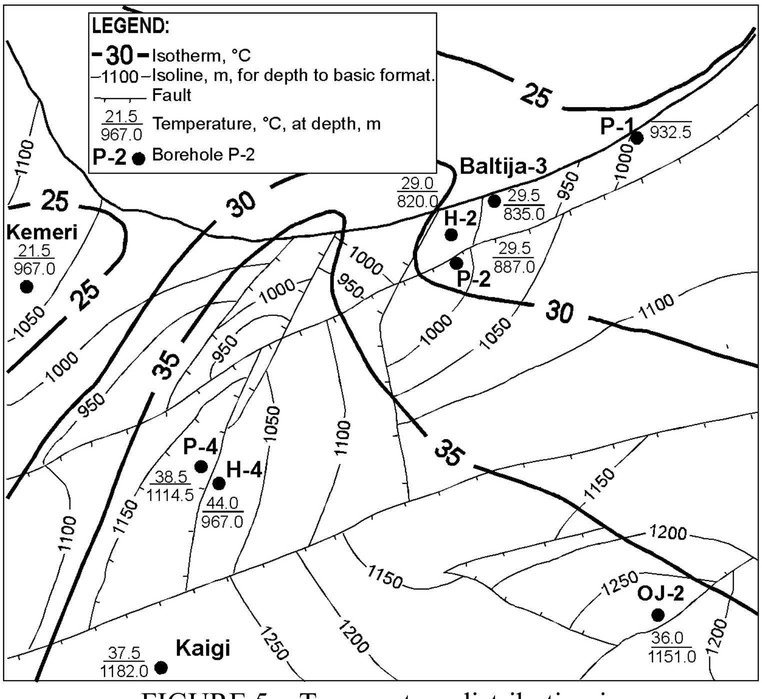

FIGURE 5: Temperature distribution in the Cambrian formations

into the feasibility of building geothermal power plants (4.5 and 8 MW) in the Liepaja and Dobele regions. These were based upon an expected yield of 50-300 m^3/hour from the geothermal wells and a temperature at the wellhead of 38-40˚C. The total thickness of the Cambrian sedimentary rocks is found to fluctuate between 74 and 104,5 m. In the region of Jurmala there are lower and higher Cambrian rock layers. Effective thickness of the sandstones is about 20 m in the interval 842-865 m and 22 m in the interval 895-919 m. Through analyses of the cross-section of the Cambrian sedimentary rocks it was concluded that the total aquifer thickness is 76 m and the effective one is 52 m in the Jurmala region.

2.4.3 Chemical characteristics of thermal water

The water of Cambrian-Ordovician aquifer system in the study area can be characterized by very high TDS content values of around 100-120 g/l (for comparison, in Reykjavík the geothermal water content is about 0.213 g/l) and by HCO_3^--Cl^--Na^+-K^+-Mg^{2+}-Ca^{2+} composition, while in the active water exchange zone HCO_3^--Ca^{2+}-Mg^{2+} type water prevails. There is an obvious gradual increase in the TDS content of the water to the south and the water similarly changes from a HCO_3^- (HCO_3^- -Cl^-) dominated composition to a Cl^- -Na^+-(Ca^{2+}) dominated one. Still, most of the territory is dominated by chloride-type water. Salinity in the Vendian-Cambrian aquifer reaches values as high as 70 g/l. Chloride-type water is very hard (10 mg-eq/l - 2000 mg-eq/l). The content of such elements as sodium, calcium sulphur is the same or similar to those found in health resorts at the Dead See. The pH variation in Cambrian waters is between 6.0-7.2. Gas in the water has the composition: N_2 - 92% and traces of other gases. For trace elements strontium is found but not H_2S. The total gas content is very insignificant and not more than 25 pm^3/l. This signifies that there will not be problems with gas collecting at the highest parts of pipelines.

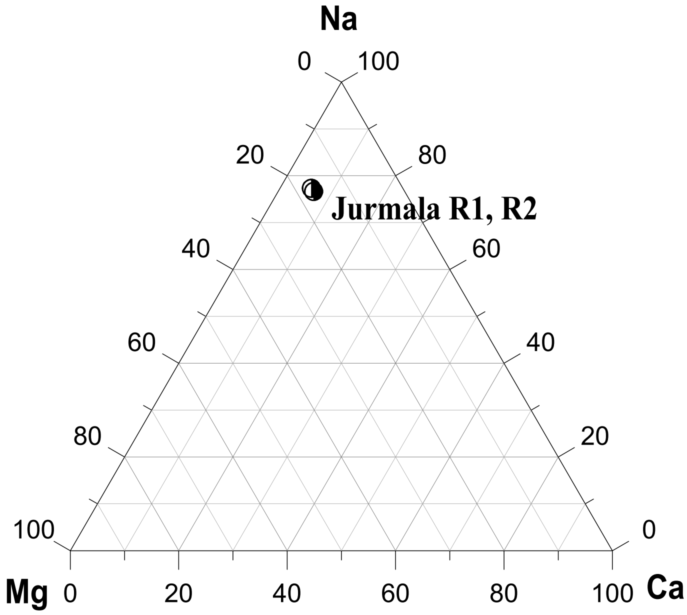

FIGURE 6: Triangular Mg-Na-Ca diagram for geothermal water in the wells Jurmala R1 and R2

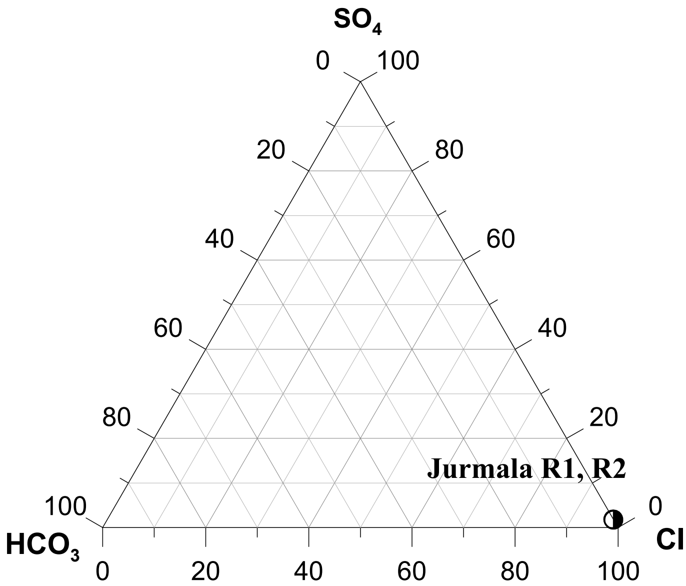

FIGURE 7: Triangular Cl-SO_4-HCO_3 diagram for geothermal water in the wells Jurmala R1 and R2

The chemical composition data from some of the wells (Appendix Table 1) in the study area were checked using the WATCH software (Arnórsson et al., 1983; Bjarnason, 1994). The ionic balance results are good, about 0.65% difference between cations and anion, which means that chemical analyses have been done correctly. Triangular diagrams (Figures 6 and 7) show percentage proportions of the major cations and anions content in this water.

Calculated enthalpy is about 126 kJ/kg. Applying chemical geothermometry simulation shows the water in equilibrium with chalcedony and that the actual temperature in the reservoir should be about 31°C or more. This temperature should suffice for the envisioned swimming pool, but because of the temperature losses in the well casing and in the transmission pipes, additional energy sources should be considered. Increasing the temperature decreases the solubility of the calcite and a few other chemical elements. But chemical computations carried out using the WATCH Computer Software show that no precipitation is to be expected (Figure 8).

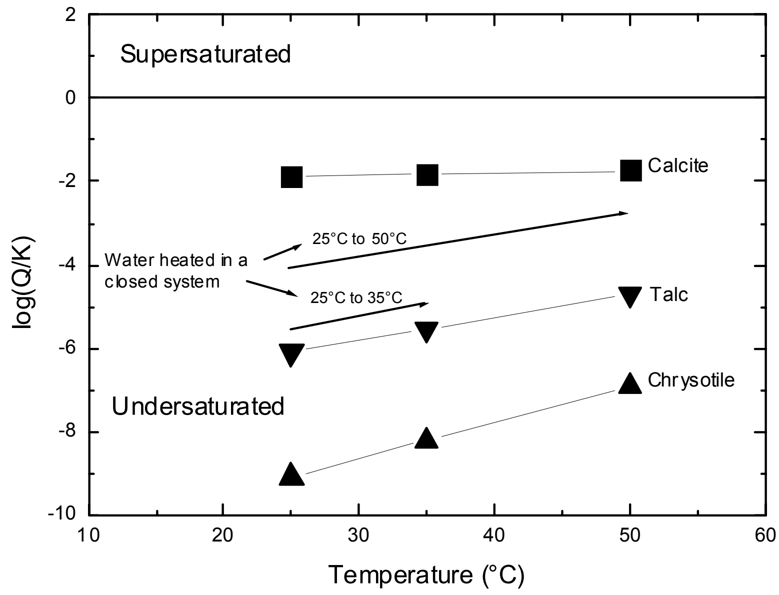

FIGURE 8: Saturation change of calcite, talc and chrisotile during heating up of geothermal water

The thermal water in the Cambrian aquifers is typically quite corrosive. Therefore, some more testing on corrosion is recommended before the material for pipelines is selected. Thermal water in the study area is characterized by high concentrations of SO_4 (1,200-1,600 mg/l), Cl (68,000-76,000 mg/l), Br (200-300 mg/l), Na (31,000-37,000 mg/l), Mg (2,400-2,800 mg/l) and K (130-480 mg/l). Water of this composition is found to be very favourable for medical treatment and also for relaxing, rehabilitation and disinfecting the skin (see Chapters 1.3 and 2.4.4), and compared to water in some famous resorts it has significant advantages (Appendix Table 1).

2.4.4 Balneological characteristics of the thermal water

Sulphur-water baths were first installed in houses in the 18th century in the study area, and doctors have exploited the mineral-rich waters since 1796. Later the curative value of the local mud was discovered. All the aquifers that yield mineral water, which might prove interesting for therapeutic utilization, as well as sources of medical mud, have been found in the western part of the region Jurmala-Kemeri.

We can see from the Appendix (Table1), that the Cambrian aquifer is more or less uniform, and the properties of geothermal water in the geothermal anomaly (Figure4) are nearly the same everywhere. The average total dissolved solids (TDS) value is 113 mg/l and it is at least 100 times greater than is required for this water to be specified as "mineral water".

Some factors determining the origin of mineral water in the study area have been categorised (Prols, 1994), such as:

- Biogenetic reduction of sulphate in the Salaspils Formation; the rate of sulphate reduction is of the order of 0.064 mg/l/day (pH = 6.7-7.2; Eh up to 200 mV);
- Dissolution of gypsum by Quaternary water permeating into the Salaspils and Plavinas formations;
- Different sedimentation ion exchange and migration processes during the Narva Basin time and later, etc.

The following types of mineral water are widely found in the vicinity of the Kemeri:

- Highly mineralised sodium chloride water containing bromine in concentrations of up to 280 mg/l and total dissolved mineral content of up to 120-125 g/l. The Cambrian formation (mainly sandstone and siltstone, approximately 70 m thick) is the most productive. During previous years this type of mineral water was utilised in health centres located in Kemeri and Jaunkemeri; estimated resources are 114 m^3/day.
- Water containing hydrogen sulphide and calcium sulphate (bicarbonate of sulphate, magnesium and calcium) with sulphate content of up to 1200 mg/l. The thickness of the productive Salaspils formation (dolomite, marl, clay, gypsum) varies from 10 to 20 m. In previous years this type of mineral water was utilised in health centres located in Kemeri and Jaunkemeri; estimated resources exceed 300 m^3/day.
- Water containing bromide, sodium and calcium chloride, with bromide content up to 14 mg/l. Most productive is the Parnus formation (mainly sandstone and siltstone, approximately 30 m thick). In previous years this type of mineral water was utilised in health centres located in Kemeri and Jaunkemeri; estimated resources comprise more than 1,700 m^3/day.
- Water containing calcium sulphate (bicarbonate of sulphate, magnesium and calcium) having a total dissolved mineral content of up to 2.0 g/l. Productive areas are the Salaspils and Plavinas formations (mainly dolomite, 15 m thick). This type of mineral water has never been exploited.
- Chloride calcium - sodium water containing bromine of up to 226 mg/l. Produced by the Kemeri formation (mainly sandstone and siltstone, approximately 115-120 m thick). This type of mineral water has never been exploited.

Such mineral waters are considered good for relaxation, treatment of neuro-muscular problems, and poly-arthritis, infertility and skin problems like psoriases. Such water is moreover beneficial for disorders of the neurological system such as post infection (meningitis, encephalitis, etc.), post stroke, spinal cord post-trauma injuries, disorders of the peripheral neurological system, complications of vertebral - spinal disorders. It is also used for disorders of the stomach, liver, pancreas and intestinal function, disorders of the kidneys, bladder and urinary systems function, prostate problems, arthritis (joint pain), high blood pressure, post surgical intervention, post heart attack, angina pectorals (chest pain), heart malformation. Because of the high TDS content in the water it is thought to be very suitable for recreational exercises, easy for moving and swimming in.

The quantity of exploitable medical mud, mostly found in the "Sloka" area (near Vaivari and Kudra), is some 362,000 m^3. It is important to stress here, that medical mud can be used repeatedly after being rejuvenated. The natural rejuvenation process takes 1.5-2.0 years, and takes place in ponds that are specially constructed for the purpose. Jurmala Resort development must be based on the utilisation of different types of available mineral water and medical mud resources there. The possibilities of bromine extraction from the Cambrian aquifer should also be investigated. The currently available data indicate that this thermal water can also be used for health problems such as external wounds, diabetes, gout, circulation problems, bronchial problems, gallstones, hardening of the arteries, palsy, haemorrhoids, neuralgia, rheumatism, neurosis, obesity, skin problems. The State Company "Latvijas Geologija" has started collating a database of mineral water composition and resources that may be used for medical and industrial purposes (Prols, 1994). The mapping of hydrogeochemical conditions and country-wide distribution of the various types of mineral water of Latvia will be undertaken simultaneously.

2.4.5 The geothermal wells

The Cambrian aquifer is confined and has a piezometric surface, the elevation of which approximates the static level of the water table in the wells. An assessment of the filtration potential of sandstones and aleurite (size between 0.05and 0.005) was made in 6 wells, and porosity and permeability measurements were made on rock samples. Data obtained during an investigation of the wells around Jurmala a few years ago are featured in Tables 6 and 7.

TABLE 6: Porosity and permeability in the Jurmala region (Freimanis et al., 1996)

Name of well	Research interval (m)	Number of samples	Porosity (%)		Permeability (mD)	
			Effective	Total	Parallel	Perpendicular
Baltija-3	853-916.7	14	17.7	19.1	484.5	481.0
Jurmala P-1	939-1011.5	29	20.5	22.7	385.0	381.5
Jurmala P-2	894.0-974.0	49	17.7	21.4	175.2	179.0
Jurmala P-4	1110.0-1218.0	32	24.9	26.8	440.0	437.9
Kemeri	968-1064.4	50	19.7	20.9	412.2	320.8
Olaine OE-2	1143.2-1222.0	36	17.8	17.9	433.3	436.6

TABLE 7: Reservoir parameters in wells in the Jurmala region assessed from measurements

Name of well	Test interval (m)	Recovery (m abs.)	Draw-down (m)	Discharge (m^3/day)	Specific discharge (m^3/day)	Trans-missivity (m^2/day)	Measured temperat. (°C)
Baltija-3	845-861	+12.3	17.35	448.5	25.9	80.0	24.3
Jurmala P-1	933-959	+11.1	12.7	235.0	18.5	70.0	22.5
	968-1016	+11.0	12.2	247.0	20.2	65.0	
Jurmala P-2	897-907	+10.8	15.76	269.0	17.1	53.0	28.0
	950-978	+10.3	32.5	213.0	6.5		
Jurmala P-4	1130-1139	+4.9	16.84	430.0	25.5		26.0
	1181-1195	+5.94	28.96	340.0	11.7	85.9	
Kemeri	967-1015	+2.92	7.95	141.0	17.6	9.7	16.0
	1038-1048	+2.92	17.65	86.5	4.9	1.7	
Kaidi	1187-1198	+8.1	3.1	80.0	25.0	27.0	
	1200-1230						
Olaine OE-2	1192-1227	+13.1	21.0	99.0	4.7	45.0	31.0

The actual production will be somewhat higher, because for "Baltija-3" well, only the upper part of the aquifer was tested. If the contribution of the lower part is included, the local experts expect production to increase to about 150-160 m^3/h (Freimanis et al., 1996).

Cambrian rocks and water temperature characteristics in well "Baltija-3" are rendered in Figure 9. There it can be seen that on the surface of the Cambrian layer the temperature is 29°C and in the deeper one it rises to 31°C. The temperature at the wellhead after a few days of pumping, taking into account that the reservoir temperature is 31°C, was calculated using the FLOWTEMP software (Arason and Björnsson, 1994). Heat loss due to pumping of the water from 845-861 m up to the surface during the test was found to be about 5.7°C (Figure 10). Long-term temperature losses will be less, because the water will gradually warm up the casing and surrounding rocks during continuous pumping.

In Table 8, data for 2 wells in the study area (R1 and R2) and 4 wells close to it are presented. As can be seen, the permeability of the rocks and the yield of the wells are nearly the same. Chemical analysis of the same wells are shown in Table 1 in Appendix.

All the data show that the geothermal reservoir is quite uniform in the study area. It means that new wells may be expected to have similar yield, as the permeability of the rocks and the chemical composition of the rock are nearly the same.

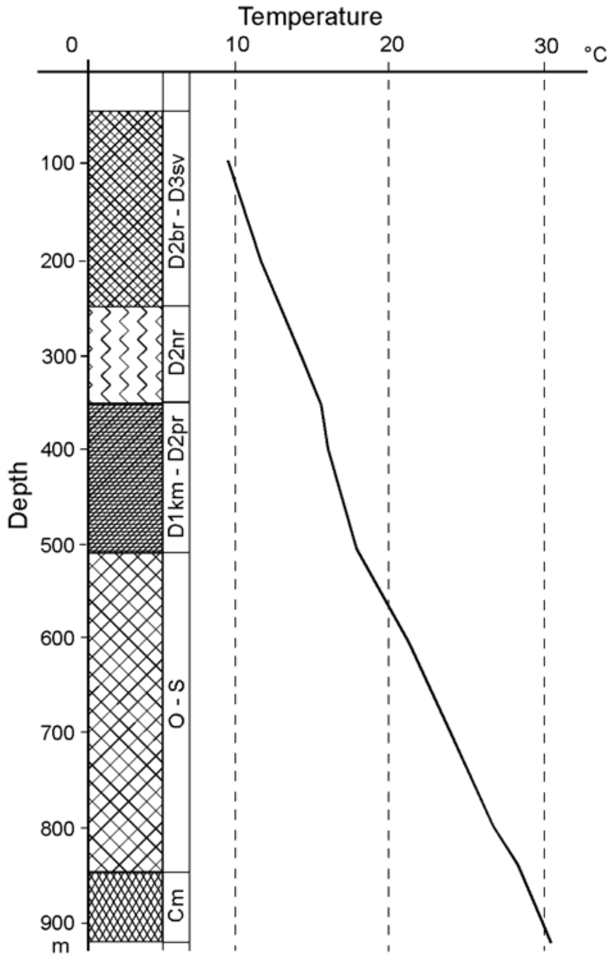

FIGURE 9: Geological profile and temperature log of borehole Baltija 3

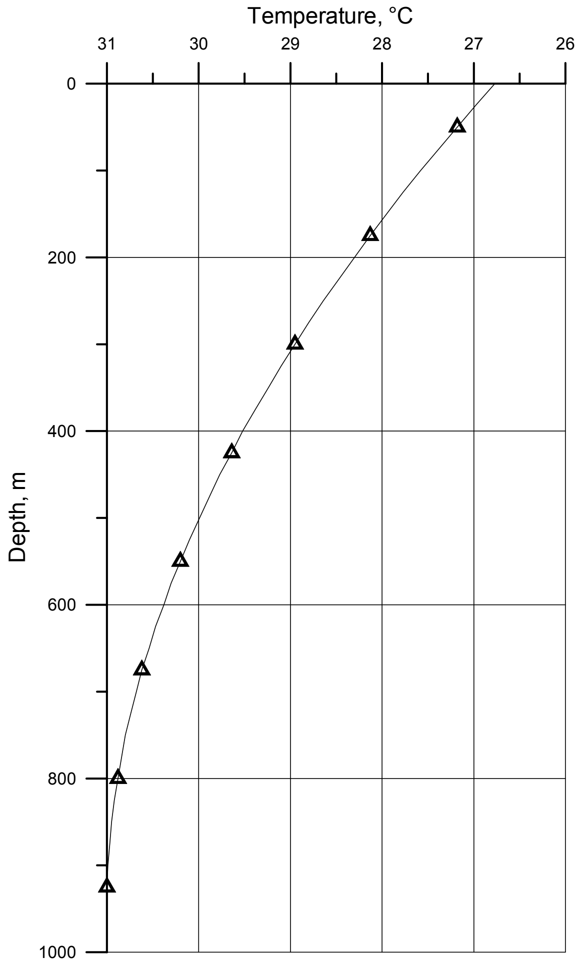

FIGURE 10: Expected flow temperature at the wellhead of Baltija 3

TABLE 8: Fluid database of the Jurmala wells and 4 others in Latvia

	Unit	**Jurmala R1**	**Jurmala R2**	**Jelgava 2**	**Bauska 1**	**Dobele P44**	**Baldone 80**
Test interval	m	933-958	897-907	1217-1239	1005-1057	1393-1428	984-1035
Sampling method		Overflow	Overflow	Overflow	Overflow	Pump	Pump
Yield (Q)	l/s	65.3	74.7	43.6	104.2	97.5	32.2
Water level	m	9.6	9.4	5.6	18.5	15.9	42.5
Reduc. water level (S)	m	12.71	15.76	4.1	36.92	8.28	9.7
Specific yield (q)	m^2/day	18.5	17.1	3.8	9.7	44.0	12
Pumping time (T)	hour	72.0/-	288.0/-	48.0/-	72.0/-	30.2/-	72.0/-
Coeff. permeabil.(k)	m/day	1.1	1.0	1.4	1.3	2.1	0.8
Permeability (k-m)	m^2/day	70.0	56.0	72.0	55.0	70.0	35.0

3. ENVIRONMENTAL ASPECTS

Nowadays large quantities of gaseous and mineral pollutants are released into the atmosphere in converting fossil fuels to thermal energy. These polluting media know no geographical boundaries. Their affects are both local and global. Latvia has, in recognition of this fact, undertaken obligations in international agreements to reduce such emissions. Geothermal energy is accepted as an environmentally benign energy source the world over, particularly when compared to fossil fuel energy sources. It is an important energy resource, the exploitation of which has relatively insignificant atmospheric pollution impact, particularly low-temperature geothermal resources. The atmospheric pollution associated with coal or oil burning for heating purposes is some 4-5 times that associated with the use of geothermal energy (see Figure 11).

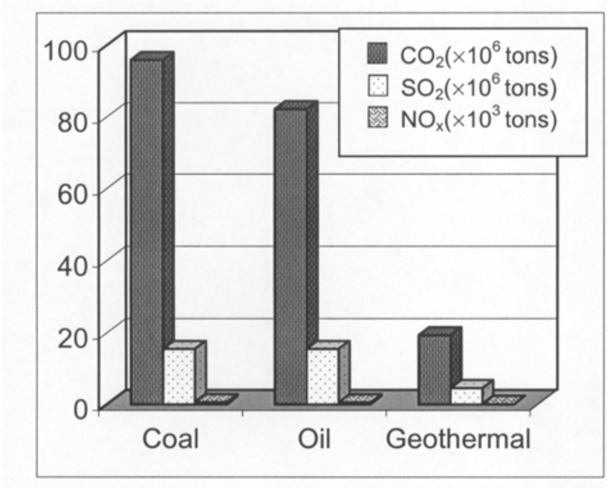

FIGURE 11: Annual CO_2, SO_x and NO_x savings by using geothermal energy (based on Hunt, 2001)

The atmospheric effects of geothermal development are chiefly from CO_2 and H_2S emissions, which are quite insignificant compared with conventional fuels (coal, natural gas and oil), as Figure 11 shows. Geothermal development during the last 40 years has moreover brought to light other impacts on the environment. These include liquid, visual and thermal pollution effects. However, it must be stressed that these effects are quite small compared to those associated with conventionally fuelled thermal developments.

The environmental impact of liquid effluent disposal in geothermal development may be minimised by employing the so called re-injection technology that entails injecting the geothermal fluid back into the reservoir once its useful thermal energy has been spent. This method has another advantage of helping to maintain reservoir pressure and thus extends both the lifetime of individual wells and that of the geothermal field as a whole. The main disadvantage of adapting this technique is cost, technical complexity and technical (mostly geochemical) difficulties associated with geothermal liquid injection. In the Latvian situation, however, the disadvantages are likely to completely outweigh the advantages for the following reasons:

- The aquifers are sandstone, which are notoriously difficult to inject into in a sustainable manner as has been brought to light by the experience of the French, the Hungarians and others;
- In the envisaged development, much of the geothermal water will, by virtue of the use to which it is being put, have to be discharged on the surface;
- The fluid temperature is low and investment revenue and earnings limited.

Compared with other renewable energy sources, geothermal energy also has many advantages. Windmills cause significant visual pollution and can be harmful to migrating birds, cannot produce rated power continuously (availability typically 30%), and their profitability is normally low except in specific instances where they replace alternatives that are economically very unattractive. Hydro energy usually means flooding of land. The amount of energy which can be produced by current photovoltaic during the element's lifetime, is less than the amount of energy needed to produce the same photovoltaic element. Geothermal development is not typically beset with such disadvantages.

4. HEALTH FACILITIES, SPORT, CULTURE AND RECREATION

Consideration should be given to extending the geothermal swimming pool project to encompass a health spa - recreational centre in order to increase its appeal and marketability. The modern generation is quite preoccupied with alternative cures free of medicines, such as natural health treatments, herbal cures, yoga etc. In the envisaged project, it should be possible to offer the visitors natural treatments, cures and health promoting activities. The following treatments and cures come to mind:

- Balneological therapy - mineral water, bromine brines for external use;
- Mud applications - sulphured hydrogen, peat and sapropel mud baths closely combined;

- Climatotheraphy - the sea, the pine wood, richly ionised air;
- Acupuncture;
- Underwater and classical medical massage;
- Medical gymnastics.

Many people realise that the best way to relax is to be active, that is why conventional sports like swimming, tennis, riding and bowling should be offered. It is recommended to organise a special swim club for children.

As previously mentioned it is proposed to locate the envisaged project close to such significant cultural centres as Riga and Jurmala (Chapter 2.3). Therefore an all-year-round attendance of the swimming pool and attached health/recreational complex has a much better chance. It has the potential of becoming a natural pastime to learn about the cultural wealth of the area in a framework of organised or individual tours. Besides the fine beach there are also good pathways though the pine forest, connecting Riga and Jurmala, ideal for walking and cycling, which are rarely used now. It is recommended that bicycles be made available to tourists for rental. Visitors can enjoy beautiful sights of the landscape simply by walking along the seacoast. For extended holiday travelling, however, facilities of a different kind should be offered that include tours to other Latvian resorts on the seacoast and some entertainment facilities for children.

In addition to the heath facilities it is recommended that recreational facilities such as a restaurant, cafeteria with a winter garden, bar, casino, billiard, and disco club be organised. A good thermal swimming pool, professional health treatment, cordial service, healthy food, and pleasant relaxation opportunities would give such a health/recreational complex a better chance of success.

5. TECHNICAL VIABILITY OF GEOTHERMAL SWIMMING POOL DEVELOPMENT

In Riga/Jurmala region there are several unused wells, one of which could be used for heating a swimming pool or there is a possibility of drilling a new one for that purpose. The sewage water after filtering can be piped about 500 m into the ocean for disposal. The low temperature of the geothermal water means that an installation of a conventionally fuelled boiler is required for covering heat losses from the pool, and to heat the building and provide hot water for showers (fuel-chips, gas or oil, capacity about 1.5 MW). (Chapter 5.4). The pool could serve three groups of clients:

- The public (people who swim for their recreation, tourists);
- Professional swimmers;
- Children (0-15 years old) who are learning to swim.

A pool size is chosen that satisfies the needs of these 3 potential client groups. The minimum size pool for professional swimmers is 25 m in length and 11 m in width. It is furthermore recommended that the pool depth be as follows: 1 m in the shallower end of the pool and 1.8 m in the deeper end, so the average depth in the whole pool is about 1.4 m.

It is assumed that during weekdays the pool will be divided between swimming lessons and general public use. This can be done by putting a removable divider-wall across the pool, opening the shallower end to children only and the deeper end of the pool to the public. Besides the main pool primarily intended for adult swimmers, a playing pool for children with small geysers, massage-seats, waterfalls, small water-slide and big water slide for children of all ages is also recommended. Moreover recommended is an indoor pool for young children and senior citizens, 4 hot pots with different temperature water (38˚C, 40˚C, 41˚C), muscle-soothing pot (39˚C), public steam bath (sauna), solarium, and facilities for the disabled. The total surface area of the swimming pool, including children's part of the swimming pool and hot pots would be about 750 m^2. Conceptual scheme of the proposed swimming pool is shown in Figure 12.

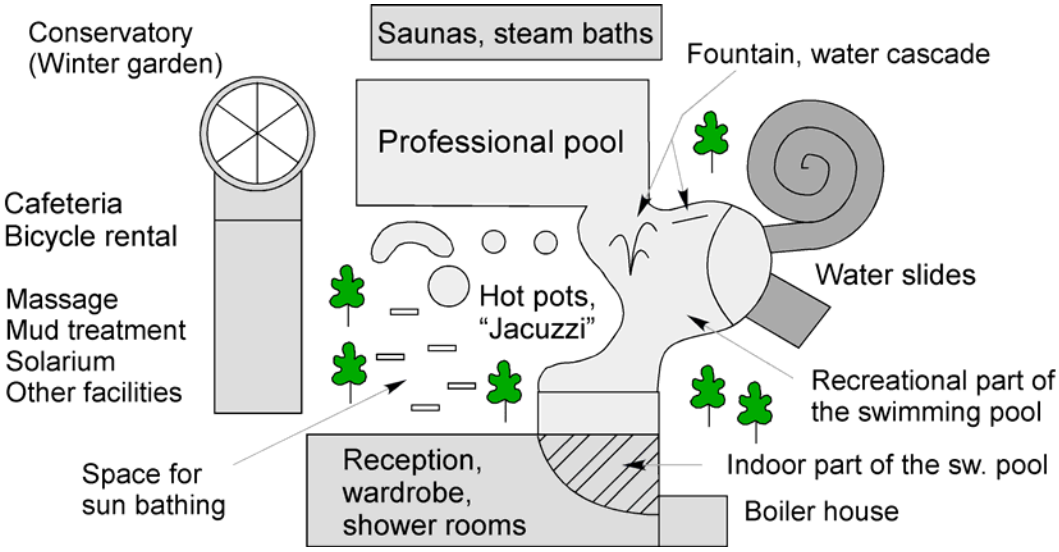

FIGURE 12: Conceptual scheme of the swimming pool

Approximately 550 children need swimming lesson out of a population of 5000 people. Each child comes once a week in a group of 15 children for a 45-minute training session. When the swimming lessons are not ongoing, some 200 guests could visit the pool facilities at the same time. This does not mean, however, that 200 people could be in the pool constantly.

5.1 The pipe system for the swimming pool

The pipe system for the swimming pool is divided into inflow and outflow pipes. The inflow pipes are connected to a few distribution spouts in the bottom of the pool. It gives better circulation and facilitates cleansing of the pool water. The wide pipes are put in the bottom before being cemented in place. The pipe material must be resistant to the water chemistry and heat. The chlorinated water is highly corrosive, and it must be assumed that water hotter than the pool-water may enter the pipes, in the event that the temperature control breaks down. The material most often used is poly-vinyl chloride, but it is preferable to use poly-propane or polyethylene because these materials are more heat resistant (Einarsson and Gunnlaugsson, 1997).

Water is admitted into the pool at the bottom of the basin and almost all the outflow is discharged through overflow culverts positioned around the rim of the pool. This overflow system is simple and successful, floating away impurities from the pool such as body fat and hair.

Special care should be taken in choosing material for the pipes carrying or in contact with the geothermal water. As was mentioned before (Chapter 2.4.3.), the chemical characteristics of some of the wells indicate that the geothermal water may be very corrosive. According to Icelandic experience in dealing with geothermal corrosion, several of the following pipe materials suggest themselves:

- Galvanised steel - practically free from corrosion in all types of geothermal water;
- Heat resistant polymer (cross-linked polyethylene, polypropylene and polybutylenes) is becoming increasingly popular for geothermal water service. An additional advantage is the ease of handling and avoidance of external corrosion problems;
- Stainless steel - some problems are encountered with stress corrosion cracking if H_2S is present in the water;
- Carbon steel - is the most widely used metallic pipe and has an acceptable service life if properly applied. It is also one of the cheapest available pipe materials.

For reduction of heat losses in the pipe system all the pipes should be insulated.

5.2 Heat loss from pool

Heat loss from outdoor pools is mainly due to the following (Svavarsson, 1990):

Convection

$$Q_c = h_c \times (T_w - T_a) =$$
$$(0.93 + 0.04 \times (31 - (-10)) + 0.45 \times 5) \times (30- (-10)) = = 164.82 \text{ cal/s m}^2 = 690.1 \text{ W/m}^2$$

where h_c = Rimsha - Doncenko heat transfer coefficient = $K + 0.45 \times v_2$;
K = $0.93 + 0.04 \times (T_w - T_a)$;
T_w = Water temperature (˚C);
T_a = Air temperature (˚C);
v_2 = Wind speed at 2 m height (m/s).

However, if it is calm outside, the wind induced cooling drops to 535.6 W/m^2 and the heat loss due to conduction reduces to half the value at a wind velocity of 3 m/s. Calculations show that it might be economically profitable to build a glass wall around the swimming pool to protect it from the wind. It is also much more comfortable for the visitors to get shelter from the wind. Experience shows that swimming pools are most visited, when it is not too windy outside.

Evaporation

$$Q_e = (1.56 \times K + 0.70 \times v_2) \times (e_w - e_a) =$$
$$(1.56 \times (0.93 + 0.04 \times (31 - (-10)) + 0.70 \times 3) \times (35.7 - 2.13) = 163.18 \text{ cal/s m}^2 = 683.24 \text{ W/m}^2$$

where e_w = Partial pressure of steam at surface (mbar);
e_a = Partial pressure of steam in air (mbar).

Radiation

$$Q_r = 4.186 \times ((13.18\times10^{-9} \times T_a^{\,4}(0.46 - 0.06\, e_a^{\,0.5}) - G_0\,(1\text{-}a)) \times (1 - 0.012 \times N^2) + 13.18\times10^{-9}\,(T_w^{\,4} - T_a^{\,4}))$$
$$= 4.186 \times ((13.18 \times 10^{-9} \times 263^4 \times (0.46 - 0.06 \times 2.13^{0.5}) - 0 \times (1 - 0.5)) \times (1 - 0.012 \times 4^2)$$
$$+ 13.18 \times 10^{-9}\,(303^4 - (263)^4)) = 69 \text{ cal/s m}^2 = 290.4 \text{ W/m}^2$$

where T_a = Air temperature (˚C);
e_a = Humidity pressure in air (mbar);
G_0 = Sun radiation in clear weather (cal/s m^2);
a = Natural reflection of water (cal/s m^2);
N = Cloudiness (1-8).

Conduction

In calculating the heat loss due to conduction, it is assumed that the pool basin is made of 18 cm thick concrete and insulated with 6 cm hard, moisture resistant rock wool. Then the heat resistance figure for the basin is about m = 6 m^2˚C/W, and the K-value, therefore, = 0.17 W/m^2˚C. For ΔT = 26˚C the heat loss is about, Q_l = 6.51 W/m^2

Rain (snow)

Heat loss due to rain occurs because the rain falling into the pool needs to be heated to the pool temperature. One mm of rain is about 1 kg/m^2. Assuming the rain to be 0˚C when it falls, it must be heated to 31˚C. For each 1 mm of even rainfall in 24 hrs the heat loss is therefore:

$$Q_p = 1\text{kg} \times 4200 \text{ J/kg°C} \times 31\text{°C}/(24 \times 3600) = 1.5 \text{ W/m}^2 \text{ mm}$$

If the maximum 24 hour rainfall in Riga in the last few years, i.e. 65 mm, is used the heat loss becomes

$$Q_p = 1.5 \times 65 = 97.95 \text{ W/m}^2$$

Total

A typical day in January is used here for the purpose of illustration. It is assumed that it is snowing slightly with a cloudy sky and wind velocity of 2.5 m/s, and the temperature is -10°C. Under these conditions the heat loss will be:

$$Q_{total} = Q_c + Q_e + Q_r + Q_l + Q_p = 683.24 + 634.05 + 290.4 + 6.51 + 94.79 = 1613.71 \text{ W/m}^2$$

Figure 13 shows the average monthly energy consumption per area of the swimming pool. Assuming that very few people come to the swimming pool when it is very cold outside and taking into consideration that energy requirements on those days are high, it is recommended to close the swimming pool for a month or two during the coldest part of the year.

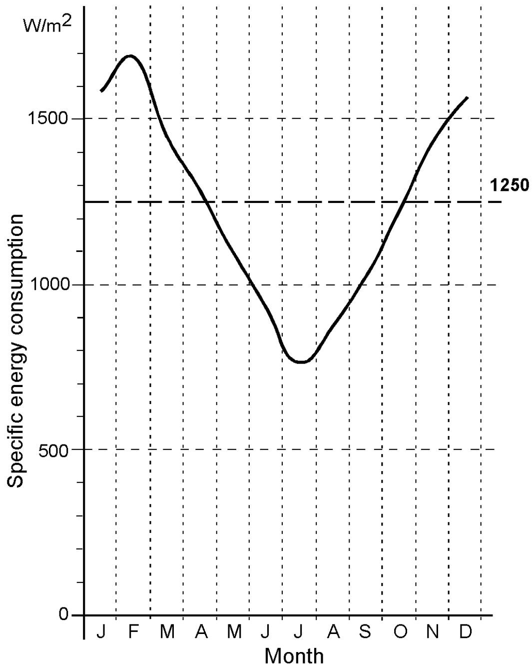

FIGURE 13: Specific energy consumption in the outdoor swimming pool

5.3 Renewal of pool water

International regulations require a certain renewal of the swimming pool water and this generally depends on pool attendance. The German regulations state that 30 litres of water should be added for each guest every day. Earlier calculations showed the upper attendance limit to be 300. Assume an average attendance of 150 persons in the pool at one time staying about 30 min. at a time. The pool is open for 10 hours a day, so 3000 persons go into the pool per day. Hence, the fresh water requirements are

$$U = 3000 \times 30 \times 10^{-3} = 90 \text{ (m}^3\text{/day)}$$
or 1.04 (l/s) on average

5.4 Energy requirement for heating swimming pool

It is assumed that a water temperature of 31°C would be suitable for the outdoor swimming pool, because it has been proven that the pools with high temperatures have more attendance than others. In Latvia the outside temperature stays lower than –10°C only for few days or weeks in the worst case, and during this period the swimming pool can be closed for maintenance and/or cleaning. The wind speed value has been reduced to 2.5 m/s assuming that a glass wall is built around the windy part of the swimming pool. It is also much more comfortable for visitors to swim when it is not windy. Available yield of the well (Chapter 2.4.5) is up to 70 l/s, but because we are not re-injecting the water back to the reservoir (technical difficulties in re-injecting into sandstone) it is supposed to use geothermal water just for renewal of pool water (2 l/s). For heat capacity of the boiler and heat exchanger calculations, the following formula was used:

$$Q = m \times c\,(T_1 - T_2)$$

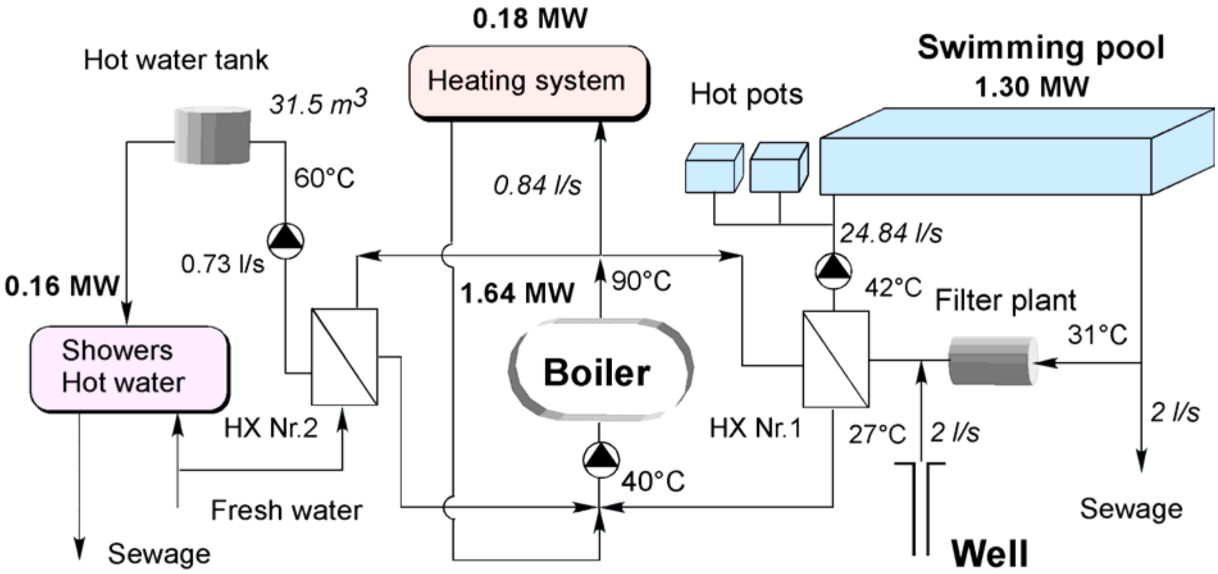

FIGURE 14: Schematic flow diagram for the swimming pool and attached buildings

where m = Flow rate of the water;
c = Specific heat capacity of the water = 4.186 J/kg˚C;
T_1 = Temperature of water at inlet (˚C);
T_2 = Temperature of water at outlet (˚C).

If, in the actual case, Latvian environmental policy will allow the use of all available mass flow from the well without re-injecting, the required capacity of the boiler (Figure 14) and, hence, the fuel consumption will be at least 2.5 times less than is assumed in this project.

Energy requirement calculations are presented in Table 2 in Appendix. As we can see in the table, energy requirements for the pool are 4 times higher than heating of the attached buildings and the energy requirements for hot water and showers. The main source of heat loss from swimming pools is by evaporation. All values in the table are assumed for the most unfavourable weather conditions. Average calculated specific energy consumption in the swimming pool was shown in Figure 13. For a swimming pool with an area of 750 m^2, the average energy consumption will be about 937.5 kW.

5.5 Disinfecting the water

Disinfecting the water for swimming pools is typically done by chloride addition. The geothermal water in the study is quite saline, sufficiently so to be self-disinfected. Like the water in the "Blue Lagoon" in Iceland, the water does not need any disinfecting additives, its own salinity is sufficient for self-disinfecting. Almost no bacteria grow there except for the blue green algae (Leptolyngbya erebi, belonging to the Cyanobacteria species), which is not dangerous to health. The water must, however, be subjected to regular quality testing to ensure that the required health authority specifications are met. However, here some chloride addition is considered for safety sake. The chloride reacts to N_2O and the outcome is HOCl and hydrochloric acid. This can be expressed as: $Cl^2 + H_2O \rightarrow HOCl + HCl$. HOCl is then split again into H and ClO. It is mainly the HOCl, which inactivates the organic material in the pool. The limits of the quantity of chloride addition to an ordinary swimming pool have been set at minimum 0.6 mg/l and maximum 1 mg/l, but this quantity usually depends on the pH value and other chemical properties of the geothermal water. The chloride addition is not taken into account in the investment cost and economic viability estimation.

5.6 Points on energy saving

It is very important to be aware of energy saving possibilities. The simple procedure of using an insulation cover over the pool when it is not being used can reduce energy requirements to almost 50% on average. Special floating covers are produced abroad for the purpose of covering pools, for their protection and are available from at least one company (Seglagerdin Aegir, June 1990). They are 5 and 7 mm thick and are mostly made of polyethylene foam, which has very good insulation properties. The cooling figure or the K value, is 3.3 - 3.9 W/m^2 for each degree of temperature difference under and outside the cover. The polyethylene foam is between two layers of protective plastic material, which is supported with nylon threads in the upper layer. The protective layer must be weather-, chemical- and sun-ray resistant. According to the producer, the polyethylene foam is not water absorbent, in case of the covering being punctured.

6. IMPLEMENTATION OF THE PROJECT

6.1 Financing

There are many possibilities for financing of projects like discussed here. It is possible to obtain partial financing of definitive, well-defined and feasible geothermal development projects in the form of a grant from EU funds, provided such a project unequivocally falls under an appropriate key-action specification set by the European Commission. There are a number of possibilities of obtaining partial financing of geothermal energy projects from special purpose financing sources such as the Nordic Environment Finance Corporation (NEFCO), the United Nations Development Programme's Global Environmental Fund (UNDP-GEF) and the various Nordic Development Co-operation Funds (here called Nordic aid), e.g. Sida, Danida, Icida etc. Soft type loans are available from several international financing institutions. Most applicable for the Baltic countries is DESLP (Danish Environmental Soft Loan Programme), which is managed by EKF (Eksport Kredit Fonden) and DEPA (Danish Environmental Protection Agency), and the World Bank's International Development Fund (WB-IDA). The above sources only provide partial financing (<40% of the total). It is recommended to develop a limited liability type company for implementation of this project.

Co-financing, joint financing, bilateral parallel financing, project financing and syndicate type of financing arrangement is necessary for a given project. An illustrative capitalisation scheme is e.g.:

- DESLP (Danish Environmental Soft Loan Programme) 30%
- Foreign equity (NEFCO/other) 25%
- Local equity (Parex bank/Unibanka) 15%
- Syndicated loan (NIB (Nordic Investment Bank)/EBRD (European Bank of Reconstruction and Development) /EIB (European Investment Bank)/BalAEF (Baltic-American Enterprise Fund) 25%
- Others 5%

6.2 Time schedule

Table 9 shows the recommended time schedule for the proposed swimming pool as it has been described above.

TABLE 9: Time schedule for designing and building a swimming pool

Planning and implementation stages of the swimming pool development	**2002**												**2003**												**2004**							
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**
Project planning	■	■	■																													
Feasibility study			■	■	■	■	■	■																								
Getting licenses, permits, equipment supply contracts, others	■	■	■	■	■	■	■	■																								
Loan approval, contract documents - project start									■	■	■	■	■	■																		
Renovation and testing of the well															■	■																
Appraisal chem. testing for corrosion, etc.															■	■	■															
Engineering design (bit documents)															■	■	■															
Implementation																																
Civil work (land (earth) proceeding, pipe laying)																		■	■	■	■											
Mechanical proceeding (boiler, pumps, heat exchangers, valves)																				■	■	■	■									
Civil work (building a swimming pool, additional buildings)																						■	■	■	■	■	■	■				
Electrical installation																											■	■	■			
Testing and commissions																													■	■		
Painting, decorating, etc.																									■	■	■	■	■	■		
Furniture, facilities equipment																													■	■	■	■
Swimming pool start-up																																■

7. ECONOMIC VIABILITY

In the following sub-chapters are outlined the viability assessment calculations for the above delineated outdoor swimming pool and health spa facility.

7.1 Investment and cost estimates

A summarised investment cost estimate for the proposed development is featured here (Table 10). In estimating the building and equipment costs, the average all inclusive budget cost figures for Western Europe (5,000 USD/m^2 for an outdoor swimming pool, 16,000 USD/m^2 for the attached building, 35,000 USD/MW for a boiler and 7,050 USD/MW for a titanium heat exchanger) were used as a basis. For Latvia a reduction coefficient of 0.3 for the buildings and 0.4 for the swimming pool was adopted reflecting the much lower wages and general cost levels prevailing in Latvia.

Costs associated with drilling a new well for the swimming pool development are not included in the cost estimates presented here. Instead it is proposed to renew an old unused geothermal well, because of the comparatively high cost of drilling a new one (1,000,000 USD).

7.2 Viability calculations

The assumptions made for further calculations are shown in Table 11. The main economical factors that have to be calculated are *PV* (Present Value), *NPV* (Net Present Value), *IRR* (Internal Rate of Return).

TABLE 10: Cost estimates

Item	USD
Outdoor swimming pool (without equipment), inclusive of planning and design	1,499,980
Indoor part of the swimming pool	80,000
Buildings attached to swimming pool	2,400,000
Swimming Pool System	
Cleansing equipment (6 sand filters and two pumps of bronze)	40,000
Boiler	56,000
Heat saving equipment	500
Stainless steal heat exchanger plant	1,128
Titan heat exchanger plant	9,165
Inlet and outlet connections to pool	1,300
Pool edge culverts and sampling pipes	9,900
Piping	51,307
Fittings	15,000
Valves, flanges and unions	11,700
Completion of equalisation tank	1,700
Pool filling, adjustments, start-up, pressure testing	600
Electricity and control equipment	
Drawings and other documentation	4,000
Control enclosures and control computer	8,000
Control equipment	3,400
Connection and installation of control system	1,200
Power cables and cable ducts	2,200
Testing and adjustment	1,800
Training and operational advice	1,200
Total costs	**4,200,080**

TABLE 11: Premises in the viability calculations

Initial capital investment (Io)	*Io*	4,200,080 USD
Loans of initial capital investment		60%
Equities of initial capital investment		40%
Interest (lending) rate	r_1	8%
Discount rate	r	12%
Loan maturity	n	7 years
Grace period	x	2 years
Economic life span	z	25 years
Tax rate on net income		12%
Annual operating cost (wages and maintenance etc.) is 1.8% from the investment		

According to the two basic adages of finance, “a dollar today is worth more than a dollar tomorrow” and “a risky dollar is worth less than a safe one”, cash flows have to be discounted (Breadley and Myers, 1991). Thus, thePpresent Value (*PV*) of a delayed payoff may be found by multiplying the payoff by a *discount factor*, which is less than 1:

$$PV = discount\ factor \times C_1$$

The discount factor, which should be less than 1, is expressed as the reciprocal of 1 plus a discount or opportunity cost of capital rate:

$$Discount\ factor = 1/(1+r)$$

The discount rate r is the reward that investors demand for agreeing to invest funds in a project that does not show immediate return on investment or may involve risk. To calculate the present value, we discount expected future payoffs by the rate of return offered by comparable investment alternatives (i.e. the discount rate). This rate is often called the discount rate, hurdle rate or opportunity cost of capital rate. To get the formula for calculating the Present Value, we should discount cash flows every year by an appropriate discount rate:

$$PV = C_1/(1+r_1) + C_2/(1+r_2)^2 + C_3/(1+r_3)^3 + \ldots$$

This is called the discounted cash flow (or *DCF*) formula. A shorthand way to write it is

$$PV = \Sigma\,(C_t/(1+r_t)^t)$$

Where Σ refers to the summation of the series from year zero to year t. To find the Net Present Value we add the (usually negative) initial cash flow:

$$NPV = Co + PV = Co + \Sigma\,(C_t/(1+r_t)^t)$$

Internal Rate of Return (*IRR*) is called the value of the discounted cash flow (*DCF*) rate of return that forces the NPV to zero in the period considered. *IRR* can thus be evaluated by means of iterative calculation from the equation:

$$NPV_{IRR} = Co + \Sigma\,(C_t/(1+IRR)^t) = 0$$

The Earnings (Revenue) calculations assume that the swimming pool will be open 300 days per year, everyday 500 people will come, ticket price is 4 USD; treatment expenses 0.5 USD, cafeteria expenses 1 USD for each person. Results of the calculations show, that earnings will be about 937,500 USD per year, Payback period 4.8 years and discounted payback period 6.6 years. In Table 3 in Appendix, are shown finance calculation results. In Figure 15 are shown major cash flows and in Figures 16 and 17 the main economic factors, Present Value, Net Present Value and Internal Rate of Return.

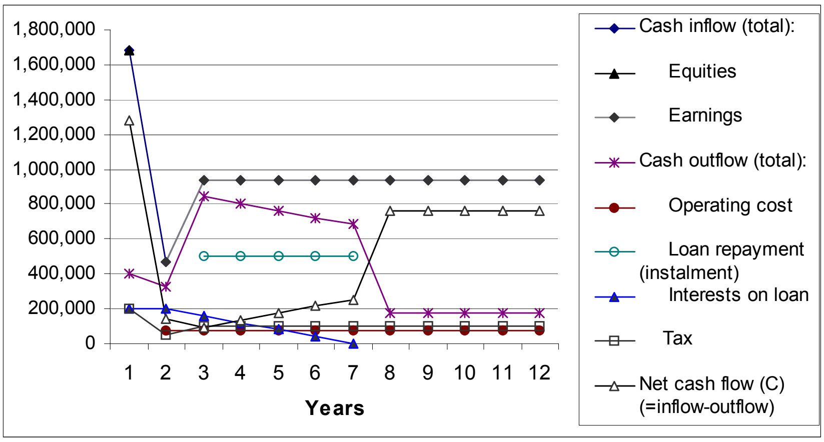

FIGURE 15: Cash flows in USD

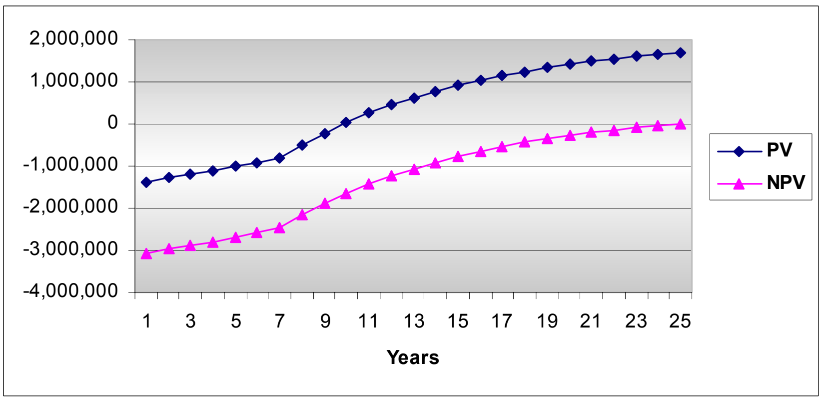

FIGURE 16: Present Value (*PV*) and Net Present Value (*NPV*) in USD

7.3 Risk analysis

First risk is related with *feasibility study* development, which may cost about 0.03% of the total investment cost. High rated investors usually have so called "Risk money" for feasibility study development of the economically promising and environmentally friendly projects.

Economical calculations in this project do not take into account the drilling of a new well (it is supposed to use an old, unused one), which according to the world geothermal experience for low-temperature geothermal fields would be 30-50% of *geological* risk. However the risk of drilling in the study area is relatively low, because the aquifer is quite uniform, chemical and geological data are similar nearly everywhere (Chapter 2.4.5.). The *operational* risks that may come up are:

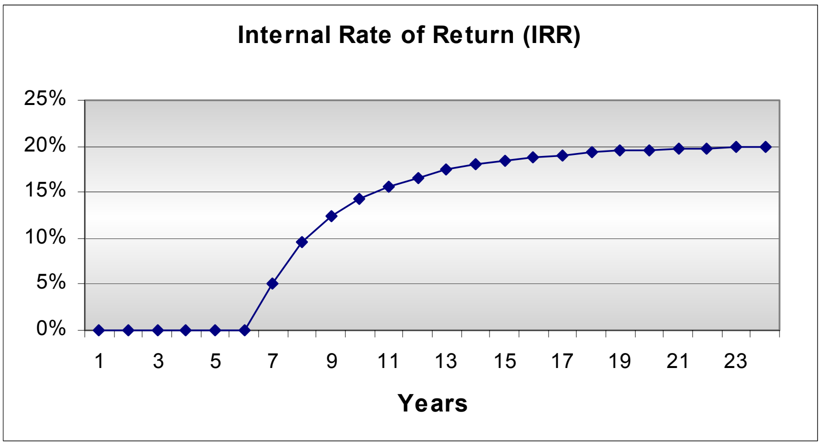

FIGURE 17: Internal Rate of Return

- Iron-phile bacteria in the well (bacteria that feed on iron) - can damage the well casing (may be eliminated by chlorination or the use of other anti-bacteria chemicals);
- Sand egress from the well aquifers through the well pump and into the system; can be eliminated by suitable sand screeners or settling provisions (used for example in France and Hungary);
- Corrosion problems (Chapters 2.4.3 and 5.1):

However, these generally have ready solutions that do not add a great dal to the overall investment.

One of the *economical* risks relates to the attendance of the swimming pool. Professional advertising of the swimming pool in Latvia and in Western Europe during the building phase, might improve the chances of the required attendance of the swimming pool. In this project it is assumed that 500 people will come to the swimming pool every day. In Reykjavik (Iceland) there are 7 different size outdoor swimming pools in an areal population of 110,000 (1999); travellers to Iceland are 262,681 (1999), and the average attendance in the swimming pools is 700 people per day per pool. In Riga the population is 900,000, in Jurmala 60,000; travellers to Latvia are 1,400 000 people. It is therefore expected that there shouldn't be any problems with attendance, taking into account the novelty of it being the first geothermal outdoor swimming pool in Latvia. The other risk factors are all *market* related and can be minimised through a careful marketing drive.

8. CONCLUSIONS

- There are "free windows" in the Latvian tourist business (currently, there is not a single outdoor swimming pool in Latvia), which would be beneficial to "fill" for future growth of the Latvian economy.
- Geothermal mineral water contained in sedimentary layers of Cambrian aquifers compares favourably with the water in famous health resorts that have proven balneological properties.
- The geological risk associated with drilling new wells in the study area is quite low based upon existing geological conditions.
- The utilisation of low-temperature geothermal fields in Riga/Jurmala region is commercially profitable *only if* it encompasses utilisation of the balneological properties of the thermal water.
- Technical and economical analysis of the Latvian geothermal resources and the technologies relevant to their utilisation demonstrate that such geothermal projects may be sufficiently viable to attract foreign and local investors.

- Implementation of a community health project of such environmental and social benefits might significantly improve the image of participating investor companies.

The following recommendations are in order:

- Before implementing the project, however, and preferably during the feasibility stage, it would be prudent to carry out further detailed geological, geochemical and hydrogeological studies of the area, and also economic viability analyses, complete with detailed market analyses. In addition, it is recommended that a reservoir simulation study be carried out. It is very important for forecasting the response of the reservoir to fluid removal for utilisation as manifested in water level drawdown, (which depends on the decided flowrate of the water taken out) the necessity for re-injection to sustain reservoir pressure, etc. The analysis of the geothermal resources in the study area for their utilization presented here has clearly shown them to be economically viable for direct use. For future development of the Latvian economy the direct involvement of Latvian energy supply companies, local banks and foreign investors in the implementation of at least one potentially really successful geothermal project, such as the one proposed here, is essential.
- The importance of selecting a good consulting company with the appropriate geothermal experience is undeniable. This is clearly borne out, for example, by the technical and political problems that have weighed down the Lithuanian town Klaipeda (next door to Latvia) district heating project to which a lack of the necessary geothermal experience is very likely to have contributed. It is therefore essential that good consultants experienced in geothermal utilisation be chosen to design and oversee the proposed open-air thermal swimming pool health spa project.
- Future geothermal studies about heat pump use for heating systems are recommended.
- The environmental policies of today are moving towards atmospheric pollution taxes being levied on energy producers using conventional fuels and trade in pollution quotas. These measures will undoubtedly affect energy prices in a way that enhances the viability of geothermal energy developments and makes them a more politically attractive alternative. Government support needs to be solicited because it will greatly facilitate the development of such geothermal developments as health spas (using the extremely mineral rich geothermal water of Latvia). A strong marketing drive should be initiated; investments and operational experience from abroad should be solicited.

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APPENDIX: Tables on chemical analysis, energy calculations and finance calculations

TABLE 1: Chemical analysis comparison of the geothermal water in wells in Latvia and in famous resorts

Fluid chemical composition of the water for selected wells in Latvia								Fluid chemical composition of the water in the famous resorts (Björnsson, 2000)						Sea water
Town, Well no.	Units	Jurmala R1	Jurmala R2	Jelgava 2	Bauska 1	Dobele P44	Baldone 80	Blue Lagoon	Dead See	Tiberias	Hamei Yoav	BaTh	Baden -Baden	
pH		5.8	6.4	6.2	5.9	6	6.1	7.37					8.2	
TDS	g/l	114.3	111.5	117.6	123.9	115.1	119	24.4	310	26	2.6	0.9	3.1	35.82
K	mg/l	440	440	-	-	-	445	1030	7560	291	15	15.4	32.9	392
Na	mg/l	33055.6	31831.8	34074.5	36518	32972.8	34679	6910	34940	5600	800	177	851	10800
Ca	mg/l	7214.4	6973.9	7128.2	7012	7320	6881.7	1100	15800	2752	113	392	144	411
Mg	mg/l	2480.8	2723.8	2739.6	2770	2602.2	2585.2	0.81	41960	595	66	51	58	1290
Cl	mg/l	70000	68400	71800	75600	70400	72600	13550	208070	15051	1566	277	1442	19400
Br	mg/l	290	215	271.7	298.3	283.8	271.7	44.5	5.6	133	4		1.6	67.3
Fe	mg/l	10	10.6	12.6	5.8	10.4	7.4	-	-	-	-	-	-	3400
Mn	mg/l	0.03	0	0	0	0	0	-	-	-	-	-	-	0.0004
Cu	mg/l	0.001	0.002	0.005	0	-	0	-	-	-	-	-	-	0.0009
Si	mg/l	-	-	-	-	-	-	219	-	-	-	-	167	-
SO4	mg/l	1243.2	1282.9	1532.1	1581.4	1438.7	1517.6	31	0.5	695	22	1	209	-
HCO3	mg/l	30.5	24.4	30.5	42.7	30.5	36.6	-	-	-	-	-	-	-
Al	mg/l	0.08	0	0.35	0.15	0	0.15	-	-	-	-	-	-	0.001
Zn	mg/l	0.005	0	0	0	0	0	-	-	-	-	-	-	-
Pb	mg/l	0.02	0.04	0.05	0.025	0.03	0	-	-	-	-	-	-	0.00003
N2	Vol. %	92.5	89	95.4	94.5	-	-	-	-	-	-	-	-	-
CH4	Vol. %	0.02	0.02	0.045	0.043	-	-	-	-	-	-	-	-	-
C2H6	Vol. %	0.0002	-	0.0002	0.0001	-	-	-	-	-	-	-	-	-
CO2	Vol. %	0.2	0.81	1	1.05	-	-	35.9	240020	-	-	193	20.4	-
H2S	Vol. %	0	0	0	0	-	-	0	-	-	-	-	-	-
He + Ne	Vol. %	1.81	4.09	2.1	2.81	-	-	-	-	-	-	-	-	-
Ar + Kr	Vol. %	0.381	0.62	0.567	0.47	-	-	-	-	-	-	-	-	-
H2	Vol. %	5.08	3.7	0.91	0.923	-	-	-	-	-	-	-	-	-
C3H8	Vol. %	0.0001	-	0.0002	0.0001	-	-	-	-	-	-	-	-	-
O2	Vol. %	0	1.12	0	0.2	-	-	-	-	-	-	-	-	-

TABLE 2: Energy requirement calculations for the swimming pool

Assumed parameters	**Symbol**	**Value**	**Unit**
Area of the pool	*A*	750	m^2
Average depth	*h*	1.4	m
Quantity of the water in the pool	*V*	1050	m^3
Area of the walls and of the bottom of the pool	*a*	1127.4	m^2
Temperature of the air	*Ta*	-10	˚C
Temperature of the water in the pool	*Tw*	31	˚C
Water inlet temperature	*Ti*	42	˚C
Temperature of the cold water	*Tc*	6	˚C
Temperature of the water from the boiler	*Tb1*	90	˚C
Temperature of the water to the boiler	*Tb2*	40	˚C
Temperature of the geothermal water	*Tg*	27	˚C
Temperature of the hot water in the tank for the showers	*Th*	60	˚C
Humidity outside	*H*	82	%
Wind speed	*v*	2.5	m/s
Heat resistance for the walls and the bottom of the pool	*r*	6	m^2˚C/W
Yield of the well	*m*	3	l/s
Sun radiation in clean weather	*Go*	0	
Natural reflection of water	*a*	0.5	
Cloudiness (1-8)	*N*	4	
Hot water use for showers		90	l/person
Max amount of people per day		700	person
Calculated parameters			
Temperature coefficient	*K*	1.77	
Heat transfer coefficient	*hc*	2.90	
Partial pressure of steam at surface	*ew*	35.7	
Partial pressure of steam in air	*ea*	2.13	
Heat loss from pool due to:			
- Convection:	*Qc*	496.98	W/m^2
- Evaporation:	*Qe*	634.05	W/m^2
- Radiation:	*Qr*	290.40	W/m^2
- Conduction:	*QL*	6.51	W/m^2
- Rain:	*QR*	94.79	W/m^2
Specific heat losses	*Qs*	1522.73	W/m^2
Total heat losses	*Q*	1.14	MW
Flow flow rate from the h.ex. (Nr1) to the sw. pool	*m*	24.84	l/s
Flow rate from the boiler to the h.ex.(Nr1)	*mb*	6.21	l/s
Flow rate from the boiler to the heating system	*mh*	0.84	l/s
Flow rate from the boiler to the hot water h.ex. (Nr2)	*ms1*	0.79	l/s
Flow rate from the h.ex. (Nr2) to the showers = fresh water inlet	*ms2*	0.73	l/s
Max hot water needs	*z*	63000	l
Hot water tank size	*P*	31.5	m^3
Heat required for ordinary building (500 m2, *Ti*=18˚C, *To*=-25˚C) ("Engineering Equation Solver" computer program)	*Qb*	176	kW
Energy requirement for swimming pool	*Q1*	**1.30**	MW
Energy requirement for the showers	*Q2*	0.16	MW
Energy requirement for the heating of the buildings	*Q3*	0.18	MW
Total boiler capacity	*Qt*	**1.64**	MW

TABLE 3: Finance calculations

Year	0	1	2	3	4	5	6	7	8	9	10	11	12
Loan	**2520048**												
Equities		1680032											
Earnings			468750	937500	937500	937500	937500	937500	937500	937500	937500	937500	937500
CF_i		**1680032**	**468750**	**937500**	**937500**	**937500**	**937500**	**937500**	**937500**	**937500**	**937500**	**937500**	**937500**
Operating cost			75601	75601	75601	75601	75601	75601	75601	75601	75601	75601	75601
Installment				504010	504010	504010	504010	504010					
Interest		201604	201604	161283	120962	80642	40321	0					
Tax		201604	47178	103428	103428	103428	103428	103428	103428	103428	103428	103428	103428
CF_o		**403208**	**324383**	**844322**	**804001**	**763680**	**723359**	**683038**	**179029**	**179029**	**179029**	**179029**	**179029**
C	**-2520048**	**1276824**	**144367**	**93178**	**133499**	**173820**	**214141**	**254462**	**758471**	**758471**	**758471**	**758471**	**758471**
Loan remainder		2520048	2520048	2016038	1512029	1008019	504010	0					
PV		-1380026	-1264938	-1198615	-1113774	-1015144	-906653	-791548	-485214	-211702	32506	250548	445229
NPV		-3060058	-2944970	-2878647	-2793806	-2695176	-2586685	-2471580	-2165246	-1891734	-1647526	-1429484	-1234803
IRR									5.1%	9.5%	12.3%	14.2%	15.6%
Year	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
Loan													
Equities													
Earnings	937500	937500	937500	937500	937500	937500	937500	937500	937500	937500	937500	937500	937500
CF_i	**937500**	**937500**	**937500**	**937500**	**937500**	**937500**	**937500**	**937500**	**937500**	**937500**	**937500**	**937500**	**937500**
Operating cost	75601	75601	75601	75601	75601	75601	75601	75601	75601	75601	75601	75601	75601
Installment													
Interest													
Tax	13428	103428	103428	103428	103428	103428	103428	103428	103428	103428	103428	103428	103428
CF_o	179029	179029	179029	179029	179029	179029	179029	179029	179029	179029	179029	179029	179029
C	**758471**	**758471**	**758471**	**758471**	**758471**	**758471**	**758471**	**758471**	**758471**	**758471**	**758471**	**758471**	**758471**
Loan remainder													
PV	619051	774249	912819	1036542	1147009	1245640	1333704	1412332	1482536	1545218	1601184	1651153	1695769
NPV	-1060981	-905783	-767213	-643490	-533023	-434392	-346328	-267700	-197496	-134814	-78848	-28879	15737
IRR	16.6%	17.4%	18.0%	18.4%	18.8%	19.1%	19.3%	19.5%	19.6%	19.7%	19.8%	19.9%	20.0%

CF_i - Cash inflow; **CF_o** - Cash outflow; **C** - Net Cash Flow; Installment - Loan repayment.